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ABSTRACT

This ERIC/SMEAC Newsletter contains a review of research from 1971 on elementary school mathematics. Research findings on teaching strategies, mathematical sentences, materials, problem solving, textbooks, and attitudes are among those cited. A list of 39 references is included. (MS)

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From The Research Of 1971 On Elementary School Mathematics†

Each year research answers some of the questions which both classroom teachers and other mathematics educators have about the teaching of elementary school mathematics. Suydam and Weaver (1970, 1971) have summarized previous research: this newsletter presents some of the answers from research published during 1971. The focus is on research that the teacher might find useful. Other studies, of more specific information to researchers, are not included.* As this bulletin was prepared, the variability of the quality of research was taken into consideration.

How effective are various teaching strategies?

Wilkinson compared the use of laboratory procedures with conventional instruction. One experimental treatment involved the use of laboratory units as a method of instruction. The laboratory units contained worksheets and manipulative materials; pupils were required to experiment with physical materials, collect data, and generalize the findings based on the data. In a second experimental treatment, cassette tapes were provided which contained a verbatim recording of all directions and questions on the laboratory worksheets. The control group was taught in a more conventional setting, using the textbook and teacher to provide the content and direction for the geometry lessons. No significant differences in achievement or attitude were found between the sixth grade groups using conventional instruction or either of the two types of laboratory procedures.

Broussard found that fourth grade students in inner-city schools given individually prescribed work through independent study, small-group discussions, large-group activities, and teacher-led discussions achieved significantly higher in skills and concepts than those taught by a traditional textbook, class-group method.

A number of studies explored aspects of the continuing question, "How effective is discovery-oriented teaching when compared with expository teaching?" Barrish tested the hypothesis that "high-divergent" students would score higher on tests after instruction under an inductive-guided-discovery strategy than those encountering a deductive-reception strategy, while the opposite would be true for "low divergent" students. The 20-day study was conducted with 125 fourth, fifth, and sixth grade children; this was followed by a retention test after 20 more days. Ten test problems called for "high cognitive" responses involving some degree of transfer, application in novel situations, or independent thinking. The remaining 25 problems were termed "low cognitive." They required recall and manipulations of algorithms in examples similar to those used in the lessons. It was found that levels of divergent production were not related to either initial learning or retention of the mathematical generalizations taught, regardless of the strategy presented. For the learning of low cognitive mathematical material, the deductive-reception strategy proved superior.

Scores of sixth graders who were taught geometry concepts with a discovery method increased over time, while scores of students taught with an expository method decreased, according to Scott.

Bassler, Hill, Ingle, and Sparks administered programmed mathematics units to students in grades 4, 6, and 8. The units differed in the amount of "guidance" which was provided. No reliable differences were found between maximal and intermediate amounts of guidance in the materials.

When data from an earlier study (Worthen, 1968) were reanalyzed with the unit of analysis changed from pupil scores to class means, no significant differences between expository and discovery strategies were found by Worthen and Collins.

Robertson found that fourth grade pupils who had seven months of expository instruction achieved significantly higher on computation tests, while those having discovery instruction scored significantly higher on the retention test on applications. Attitudes were significantly higher for the discovery group. The teachers were able to adapt to new techniques and procedures, and teacher behaviors in the discovery approach differed significantly from those in the expository approach. Robertson concluded that "it would appear that **no one treatment or mode of instruction can be considered the best approach.** The teacher who learns as many instructional modes as possible, identifies and diagnoses pupil needs and abilities, and uses this knowledge to individualize instruction may very well get the best results."

† Prepared by Marilyn N. Suydam, Faculty Research Associate, ERIC/SMEAC

How do pre-school and kindergarten children acquire mathematical ideas?

As in previous years, the studies which focused on Piagetian theory were variable in both topic and findings. Many were concerned with types of training, largely on conservation. An even greater number measured the stages and ages of development, again with most related to conservation, but a few on topics such as transitivity and implication-reasoning. Several focused on the relationship of conservation and race, SES, age, verbal ability and similar factors. Learning style was considered in one case. The findings of these studies have value to future researchers, and to those who are attempting to block out the "map" of the Piagetian realm, but little clear evidence that is useful to the classroom teacher has been added.

Carr reported no significant differences were found on four Piaget-type tests between kindergarten groups who used Bereiter-Engelmann materials for two, one, or no years. The program appeared to be more effective for kindergarten children than for pre-kindergarten children. The four tests assessed the child's ability to conserve number, to discriminate, to seriate, and to enumerate.

In a continuing set of reports on a survey of kindergarteners, Rea and Reys reported specific data on knowledge of children in the areas of geometry, number, money, and measurement. Use of an **informal but planned** sequence of experiences was recommended.

How do children achieve with various types of mathematical sentences and algorithms?

Engle and Lerch reported on a study designed to ascertain whether first graders could make correct decisions about basic addition ideas stated as either true or false number sentences. A test was developed, with one part having addition combinations stated in the form $\begin{array}{r} 4 \\ +3 \\ \hline \end{array}$ and $3 + 4 = \square$, and the other part composed of closed addition sentences, for which pupils were to indicate whether each was true or false. First graders who had studied in programs without emphasis on closed number sentences could make decisions about basic addition facts stated as either true or false number sentences with a reasonably high degree of accuracy. No significant difference was found in their ability to answer the computational-type addition and their ability to make correct decisions about closed sentences concerning similar addition ideas.

Weaver analyzed the relative difficulty of various open-sentence types. He found that sentences of the form $\square - b = c$ or $c = \square - b$ were significantly more difficult than were sentences of the form $\square + b = c$ or $c = \square + b$ for children in grades 1 through 3. He also found that the position of the placeholder in the sentence affected the difficulty of the sentences. That is, sentences of the form $a + \square = c$ were less difficult than sentences like $\square + b = c$.

Steffe and Johnson found that mean scores for problems of the type $a + b = \square$ were higher than for the three other problem types studied: $a - b = \square$, $a + \square = c$, and $\square + b = c$. They also reported that first graders solved problems with no described action as well as they solved problems with described action.

Trafton investigated the effects on third grade pupils of two initial approaches to two-digit subtraction. One approach consisted of the conventional decomposition algorithm. The second approach involved a more general method based on the main concepts of subtraction and using the number line as an aid to solution, before work with the decomposition algorithm. The "general" approach did not result in greater understanding of or performance with the decomposition algorithm than did prolonged development of the algorithm.

Aims reported that the number of frames to the left of the equality sign and the arrangement of operators ($+, -, \times, \div$) affected the time needed to solve arithmetic examples, but the number of possible solutions did not significantly affect time. He analyzed data from students in grades 4 through 8.

What is the role of materials in mathematics?

The role of materials in the learning of mathematics is being questioned by teachers at all levels today. Generally, we are bound philosophically to their use: but research increasingly indicates that we need to analyze **when** they are used, **with whom** they are used, **what types** should be used, and **how** they are used.

Bisio, conducting a study with 29 classes of fifth graders, compared three methods of teaching addition and subtraction of like fractions. In one treatment neither the teacher nor the students used manipulative materials. In the second treatment, the teacher used the manipulative materials as a demonstration for the students. And in the third treatment, both teacher and students manipulated materials. Children taught with manipulative materials, both **using** them **and** passively watching them being used, scored higher than those not using materials.

Knaupp also found that both teacher-demonstration and student-activity modes, using blocks and sticks in presenting addition and subtraction algorithms and ideas of base and place value to four second grade classes, resulted in significant gains in achievement.

The assumption that the use of materials can contribute significantly to the learning of mathematics was also investigated by Carmody. She studied three sixth grade classes who were assigned to concrete, semi-concrete, and symbolic treatment groups for an 11-day unit on selected numeration and number properties. Support was found for the use of concrete or semi-concrete approaches over symbolic approaches if the goal of instruction is transfer.

Johnson assigned three treatments to students in grades 4, 5, and 6 who were studying perimeter, area, and volume. The "Maximum" treatment used a semi-programmed text and two sets of physical models and instruments for each child; students were directed by the text to make use of the objects and were free to use them at other times as well. In the "Moderate" treatment, students used the programmed text, including all drawings and illustrations, but were not given the models. In the "Minimum" treatment, all drawings and illustrations were removed and verbal descriptions were substituted; no models were given. He reported that a high degree of concreteness resulted in higher mean achievement and retention scores.

How useful are mathematics tests?

After analyzing a standardized mathematics test, Gridley reported that mathematics achievement in grades 2-5 as measured by the test appeared to consist of several empirically defined clusters of items. The clusters varied from grade to grade, and subtest headings did not represent distinct clusters. The meaningfulness of the total score, as well as the subtest scores, was questioned, since several skills or abilities were being measured.

What factors affect problem-solving ability?

Kamins attempted to determine if the appearance of familiar settings, things, people, and subjects in the language of word problems would affect the success of black children from a lower socio-economic environment in solving word problems. For the 32 fifth graders involved, no significant difference in achievement was found between use of problems written by children and textbook problems. (However, in another study outside the problem-solving context, Knight found that pupils taught and assessed using a sub-culturally appropriate language in a unit on non-metric geometry performed more successfully than those taught and assessed using standard language in the primary grades.)

Nickel devised a multi-experience approach to verbal problem solving, using abstract, representational, and concrete materials. This was more effective for fourth graders than a strictly verbal approach.

Four variables which significantly affected the difficulty of word problems were identified by Loftus: number of operations, sequence of problems, complexity, and conversions. Verbal clues, order of operations, and number of steps had little effect on difficulty level. For the study, she used a computer-based teletype-presented program of 100 problems, and analyzed data from 16 sixth graders.

Cromer analysed the difficulty of multiplication problems for fifth graders. He found that difficulty level could be predicted by problem characteristics such as order, digital, or process variables.

What do studies on the vocabulary of textbooks show?

Willmon found a total of 473 technical mathematics words in 24 textbooks for grades 1-3, with frequency of use ranging from 1 to 5,995. Seventeen words were repeated more than 1,000 times, but most were used less than 25 times. Stevenson reported that, of 396 technical and semi-technical words he found in third grade mathematics textbooks and first and second grade readers, only 51 were used in both reading and mathematics books. However, 161 words were common to all four mathematics textbooks. Data from a study by Browning is less encouraging. She found a total of 743 mathematical terms in 15 textbooks used in grades 4, 5, and 6; only 10 words were common to all textbooks.

These studies indicate that every teacher of mathematics must consider the reading problem which a child may face. Smith added further evidence on this point. He found that the composite readability scores for sixth grade textbooks ranged from 5.0 to 5.8; however, analysis of selections indicated a range of below grade 4 to grade 8. Tests ranged only from below grade 4 to grade 6 in reading level.

In a different type of vocabulary study, Olander and Ehmer administered a test from 1930 to pupils in 1968. On the Buswell-John Vocabulary Test, 1968 pupils achieved higher scores on 74 of 100 items in grade 4, 59 items in grade 5, and only 48 items in grade 6 than did pupils who had taken the test in 1930. On a test of contemporary terms, mean scores were 49 for grade 4, 58 for grade 5, and 64 for grade 6 on the 100 items.

What type of homework is helpful?

The evidence on this topic is still rather nebulous. Grant found no significant differences in achievement between fifth grade groups given differentiated homework on two levels of difficulty, textbook assignments, or no homework. Gray and Allison also reported that no significant differences were found when students were given three or no homework assignments per week in grade 6.

What is the status of children's attitudes toward mathematics?

Deighan, in a study with students in grades 3, 5, and 6, found that attitude toward mathematics was not significantly related to mathematics achievement, nor was there a significant relationship between teachers' and students' attitudes. A significant decrease in students' attitude scores across grades was found. Malcolm similarly found that attitudes toward mathematics became less positive from grade 3 through grade 7.

Findings such as these have been reported in the past—but there are other studies which present differing evidence. There are obviously many factors involved when attitudes are measured: the type and quality of the instrument used for the measurement, what has occurred to the children immediately prior to administration of the instrument, and numerous other points could be noted. For any one teacher it is less important to know how children in general feel about mathematics than it is to know how a specific class feels—and the attitude of a single group can usually be judged in many ways by their teacher . . .

*** For other studies . . .**

Many other studies might have been cited—for instance:

Weeks reported that training with attribute blocks for eight weeks in grades 2 and 3 had a strong positive effect on logical and perceptual reasoning ability.

Sension found that area, set-subset, and combination representations for introducing rational number concepts appeared to be equally effective on tests containing items consistent with the experimental instruction. However, the combination treatment produced a higher level of generalization to a number line model.

Sowder found that pupils in grades 4-7 needed about three to six instances to form generalizations of the sort tested from numerical situations. Only rarely were generalizations formed after six unsuccessful instances.

A complete annotated listing of studies published during 1971 is available from ERIC/SMEAC and also in the November 1972 issue of the **Journal for Research in Mathematics Education.**

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Wilkinson, Jack Dale. A Laboratory Method to Teach Geometry in Selected Sixth Grade Mathematics Classes. (Iowa State University, 1970.) *DAI* 31A: 4637; Mar. 1971.

Willmon, Betty. Reading in the Content Area: A "New Math" Terminology List for the Primary Grades. *El. Eng.* 48: 463-471; May 1971.

Worthen, Blaine R. A Study of Discovery and Expository Presentation: Implications for Teaching. *J. Teach. Ed.* 19: 223-242; Summer 1968. (see also Worthen, *J. Ed. Psychol.* 59: 1-13; Feb. 1968.)

Worthen, Blaine R. and Collins, James R. Reanalysis of Data from Worthen's Study of Sequencing in Task Presentation. *J. Ed. Psychol.* 62: 15-16; Feb. 1971.

**"DAI" refers to *Dissertation Abstracts International.*

Compilations and Reviews of Research

If you are interested in securing copies of compilations of research on elementary and secondary school mathematics, here are some sources:

1. "An Evaluation of Journal-Published Research Reports on Elementary School Mathematics, 1900-1965." Volumes I and II. M. N. Suydam, unpublished doctoral dissertation, The Pennsylvania State University, 1967. Microfilms Abstract Order No. 68-3563; available from Xerox University Microfilms, Dissertation Copies, P. O. Box 1764, Ann Arbor, Michigan 48106; cost, $4 for microfilm and $10 for xerography.

   This initial study contains categorized, annotated, and evaluated reports of 799 studies (grades K-8) plus a list of approximately 700 dissertations. Bibliography.

2. "Interpretive Study of Research and Development on Elementary School Mathematics, Phase I." M. N. Suydam and C. A. Riedesel, Final Report, June 1969.

   Volume I, Introduction and Summary: What Research Says. ED 030 016. 255 p. Microfiche (MF), $0.65; Paper Copy (HC), $9.87

   Volume II, Compilation of Research Reports. ED 030 017. 331 p. MF, $0.65; HC, $13.16

   Volume III, Developmental Projects. ED 030 018. 232 p. MF, $0.65, PC, $9.87

   Available from ERIC Document Reproduction Service (EDRS), Leasco Information Products, Inc., P. O. Drawer 0, Bethesda, Maryland 20014.

   Volume I contains synthesized research findings in the form of answers to numerous questions. Volume II contains categorized, annotated, and evaluated reports of studies and dissertations for 1900-1968, extending the list of those cited in the dis-

sertation above. In Volume III are summaries of projects, with typescripts of interviews with nine project directors. Bibliography in Volumes I and II.

3. "Using Research: A Key to Elementary School Mathematics." M. N. Suydam and J. F. Weaver, 1970.

   This set of 11 bulletins synthesizing research findings is available by individual titles from EDRS; the complete set of bulletins is currently out of print. An updated collection is anticipated and will be announced in this Newsletter when it is available.

4. "Annotated Compilation of Research on Secondary School Mathematics, 1930-1970." M. N. Suydam, Final Report, February 1972.

   Volume I, Introduction; Compilation of Articles. ED 062 165. 407 p. MF, $0.65; HC, $16.45

   Volume II, Compilation of Dissertations; Summary and Conclusions. ED 062 166. 411 p. MF, $0.65; HC, $16.45

   Available from EDRS at cost cited above; also available from The Center for Science and Mathematics Education, The Ohio State University, 244 Arps Hall, Columbus, Ohio 43210 at a cost of $8.50 for the set of two volumes.

   Volume I contains categorized, annotated, and evaluated reports on 780 studies (grades 7-12), while 770 dissertations are similarly presented in Volume II. Some studies for grades 7-8 were included in previously completed elementary compilations. Bibliography in each volume.

5. "A Review of Research on Secondary School Mathematics." M. N. Suydam, March 1972.
   Available from EDRS, document SE 014 234, 229 p., MF, $0.65, HC, $9.87; also available from The Center for Science and Mathematics Education, address above, at a cost of $3.50

   This is a review of research findings in the form of answers to numerous questions. Bibliography.

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Citations and abstracts are also obtained from **Selected Documents on the Disadvantaged** and **Office of Education Research Reports**, 1956-65. Journal Articles which were indexed for **Current Index to Journals in Education** 1969, 1970, and 1971 are also included. All of this material is organized into four sections: Subject Index, Author Index, ERIC Documents, and ERIC Journal Articles. Each microfiche collection will be arranged in numerical sequence in an attractive, functional case.

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A twelve-page guide entitled "ERIC: How to Use It for Mathematics Education" has been developed by and is available from ERIC/SMEAC. The guide presents a summary of pertinent information concerning the ERIC system, with emphasis on mathematics education functions and is directed primarily to those individuals needing a ready digest of ERIC services and procedures.

Single copies are available at no cost from ERIC/SMEAC. Similar documents are available through ERIC/SMEAC for science education and for environmental education.

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